Nuclear Weapons Effects: Agent Defeat Simulations

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We performed several nuclear weapons effects simulations for neutralizing chemical agents through nuclear detonations. These calculations involved performing coupled radiation-hydrodynamics calculations in an implicit manner in the presence of multiple materials requiring complex equations of state. Figure 1 shows a 1.5-kT earth penetrator at detonation inside an underground bunker (modeled as a sphere) and the blast wave at 8 μs after detonation. This part of the blast wave calculation was done in Lagrangian mode as a separate component by resolving a three-dimensional (3D) sphere. The results of the calculation were then mapped onto the full system grid. Merri Wood-Schultz had earlier observed that the radiation from such a small detonation never escapes the blast wave because of very high opacity of iron. This calculation confirms her finding.

Figure 2 shows the bunker geometry just at the time of the impact of concrete with the chemical agent (at 51 μs after the detonation). Shortly after the impact, a strong shock propagates through the agent and results in sustained temperature (for several hundred μs) exceeding 10,000 K that is sufficient to completely destroy the agent.

We are currently performing similar agent-defeat calculations on a much larger scale involving hundreds of agent drums stored inside storage sheds above ground. Figure 3 shows the vorticity plots at three different times for an above-ground explosion of the same 1.5 kT device in an area the size of a football field containing two storage sheds, one containing 100 55-gal. drums containing solid radioactive waste, and the other one containing 100 55-gal. drums containing a chemical agent. Only the right bottom part of the mushroom cloud is visible in the figure because the rest of the cloud already has escaped the problem domain. The calculation indicates a significant amount of turbulence is being generated even before the cloud starts interacting with the structures. Because of the size of the problem, it is not possible to calculate this turbulence through direct numerical simulation even on our massively parallel supercomputers. We plan to invoke turbulence transport models available in our code to capture the effects of this turbulence. Only an implicit multimaterial shock hydrodynamics code that solves the full Navier-Stokes equations could realistically be expected to perform such calculations. We have this unique capability.

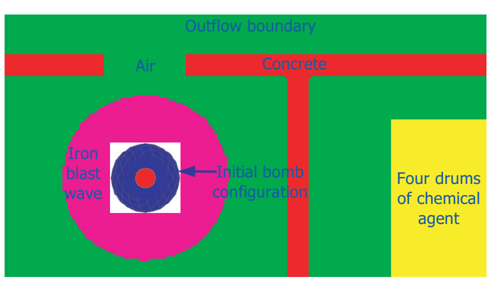

Figure 1—
A ground-penetrated 1.5-kT nuclear detonation inside an underground storage room. The pink (large) sphere shows the location of the blast wave at 8 microseconds. All radiation energy for such a small yield remains confined within the blast wave and does not directly contribute towards the agent's destruction.

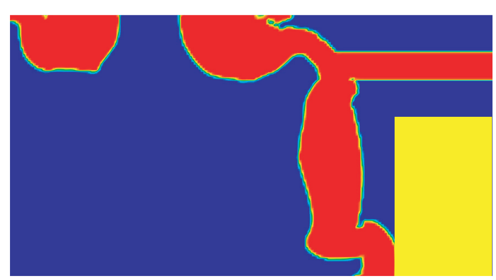

Figure 2—
Bunker wall and agent geometry just before the concrete wall impacts the agent (at 51 s after the nuclear detonation).

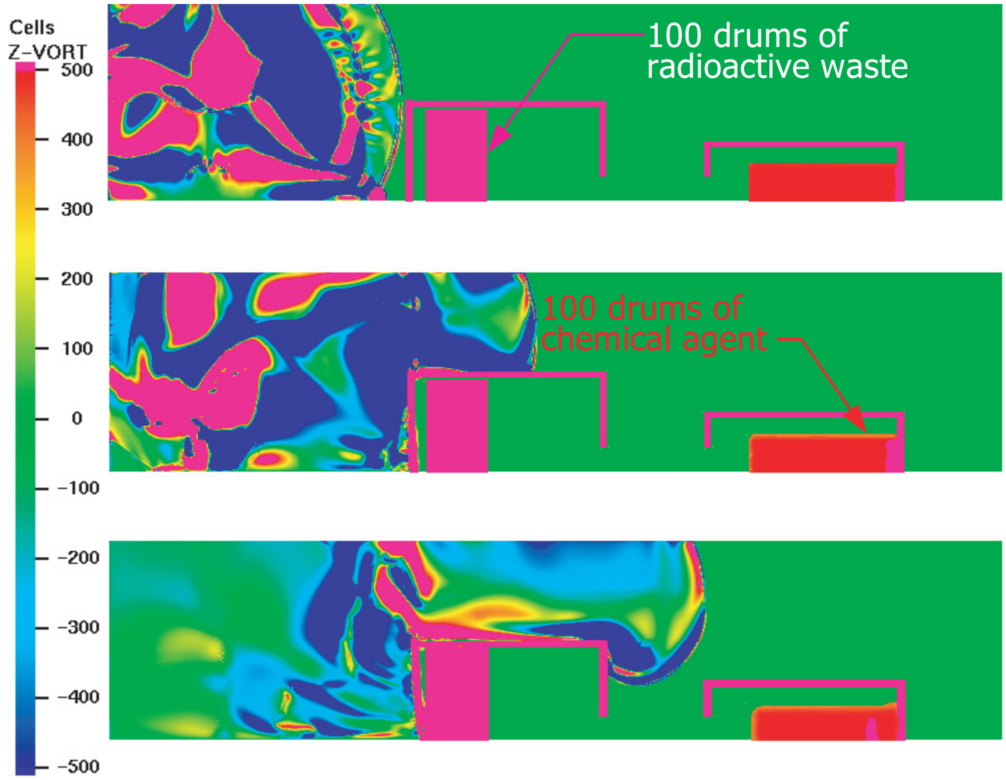

Figure 3—
Color-coded vorticity contours in the right bottom part of the mushroom cloud following an above ground 1.5-kT nuclear explosion.

We also performed detailed 3D coupled radiation-hydro calculations simulating a 10 kT nuclear detonation inside the U16B tunnel at the Nevada Test Site (Fig. 4). The mountain above the tunnel was modeled also to include the effects of fluid-structure interaction. A detonation of about this magnitude was found necessary for radiation to penetrate through the entire length of the tunnel indicating that such yields might be necessary to guarantee agent destruction stored inside large tunnel complexes.

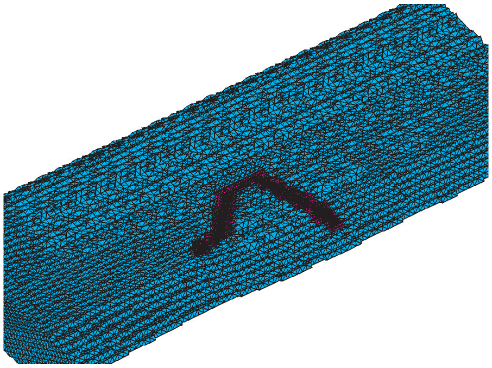

Figure 4—
U16B tunnel including the mountain above the tunnel. Part of the mountain is stripped off in this figure to make the tunnel visible.

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